RELIABILITY OF TREE-HEIGHT MEASUREMENTS IN NORTHERN HARDWOOD STANDS

Abstract. No significant differences were found between the heights of standing hardwood trees estimated with a Haga altimeter and actual heights measured after the trees had been felled. Differences ranged from +10 feet to —12 feet, and the mean difference for all trees was 0.1 foot.

Accurate height measurements of standing trees are required of foresters in many phases of their work. One problem is: what instruments will provide the accuracy required? Another is that heights of standing hardwood trees are difficult to estimate because their crowns are so irregular that one cannot easily determine what actually is the highest point of the tree. For this reason, measurements of hardwood tree height are often taken during the leafless season when the highest point of the crown is easier to see.

The accuracy of various height-measuring instruments has been reported by Warren (*1958*); he found that most discrepancies were not caused by the instruments. However, most comparisons of tree height have been made on softwoods, which have an easily discernible tip. Gibbs (*1964*) has demonstrated the accuracy of the Spiegel-Relascope for measuring heights of oaks and other hardwoods under leafless conditions. And Hunt (*1959*) has reported that the Haga altimeter is faster to use, is easier to handle, and is graduated more precisely than most other instruments.

1

A recent study of site index in the White Mountains of New Hampshire provided information for determining the accuracy of height estimates of standing northern hardwood trees under full foliage conditions. Heights of 70 standing trees (12 paper birch, 17 yellow birch, 20 sugar maple, 11 red maple, and 10 white ash) were estimated in mid-summer 1966 with a Haga altimeter. Then each tree was felled and actual height was measured with a 100-foot tape.

The actual tree heights ranged from 47.7 feet up to 92.7 feet, and differences between the estimated and actual heights ranged from +10.0 feet to −12.0 feet. The average difference between the two sets of measurements was less than 0.1 foot for all trees combined, and no discernible variation among species was found.

Some differences between estimated and actual heights were due to the scale of the altimeter not facilitating measurement closer than 0.5 foot. However, 28 percent of the trees had differences greater than ±5 feet. These larger differences may have been caused by trees leaning toward or away from the observer, or by the observer's not using the same tip for both measurements. The following tabulation shows the proportion of height estimates that were within a given number of feet of the actual measured height:

Feet	Percent
1.0	26
2.0	37
3.0	47
4.0	60
5.0	72

Mean height of the 70 trees as estimated with the Haga altimeter was compared with actual mean height, using a paired "t" test. No significant difference was found at the 95-percent level. Also, the measurement error was not significantly different among tree-height classes. Using the variance among individual differences calculated for this test (24.25) and using a $t_{.05}$ of 2, we could estimate the measurement error associated with the calculated mean height of a given number of sample trees measured with a Haga altimeter:

$$n = \frac{S^2 t^2}{(M.E.)^2} \tag{1}$$

Using formula (1) with the above variance (24.25) based on 70 degrees of freedom, we found that the following numbers of trees are required to be within the given measurement errors with 95-percent probability:

2

Measurement error ($\pm$ *feet*)	Trees (*number*)
1	97
2	25
3	11
4	7
5	4

For example, on a small plot, if four trees qualify as site-index trees and all are measured with a Haga altimeter, the above tabulation indicates that the calculated mean height would be within 5 feet of the true mean height of those four trees. If greater precision is desired, additional measurements could be taken on the same trees to reduce measurement error. Note, however, that the error in the tabulation above is measurement error only and does not include sampling error. To estimate mean stand height (as opposed to mean height of the sampled trees alone) when all qualifying trees cannot be measured, it would be necessary to use more trees than indicated above to account for sampling variation.

Literature Cited

Gibbs, Carter B.
1964. SPIEGEL-RELASCOPE RELIABLE FOR MEASURING TOTAL HEIGHTS OF STANDING HARDWOODS. J. Forestry 62: 580.

Hunt, E. V., Jr.
1959. A TIME AND ACCURACY TEST OF SOME HYPSOMETERS. J. Forestry 57: 641-643.

Warren, W. G.
1958. TESTS OF SOME INSTRUMENTS FOR MEASURING TREE HEIGHT. New Zeal. Res. Note 12, 18 pp.

—DALE S. SOLOMON and RICHARD J. NOLET[1]
Forest Service, U.S. Department of Agriculture

■

[1] Mr. Solomon is associate mensurationist at the Northeastern Forest Experiment Station's research unit at Durham, New Hampshire; Mr. Nolet is forester on the White Mountain National Forest, Gorham, New Hampshire.